SOFTWARE ENABLED CONTROL FOR SYSTEMS WITH LUMINENT DEVICES

REFERENCES

This application is a continuation in part patent for pending application for the Electro-Optic System Controller and method of operation SN 09/724, 692. This utility patent is also filed based on Provisional Application number 60/457, 095 titled Software Enabled Control System for Electro-Optic Device.

BACKGROUND

Field of the Invention

The invention relates to methods used to control a system containing a luminent device. Possible luminent devices can be, but are not limited to, a laser, a light emitting diode, and a cold cathode fluorescent light. The invention teaches methods for control that rely on mathematical models that can be configured dynamically in order to satisfy the requirements for any luminent device. A Host processor carries out the configuration.

Description of the Prior Related Art

Present approaches use a variety of solutions. Existing control approaches for luminent device systems are generally based on specific analog or digital circuits to implement

functions. The specific nature of these control approaches renders them inflexible and unable to change when the luminent device is changed, or with changing environmental conditions, situations in the field, or with the type of application. Changes to address different conditions need to be carried out with a laborious and time-consuming process of design and characterization. In the specific case of laser controls, some existing control systems utilize a variety of methods in circuit form or programmed in a processor. These methods are dependent on some form of control dependent on a specific algorithm. The prior art methods rely on an external characterization of the laser. These methods also are fixed for a specific laser. Many prior art methods also rely on elaborate and hardware-oriented implementations used to address the specific application. Any adaptations or changes to these controls also require laborious redesign and operation cannot easily be changed in the field as the luminent device ages.

SUMMARY OF THE INVENTION

Software enabled control is a method that allows dynamic configuration of the operation of a control system. The configuration can be done in a factory calibration or while the system is running in the field under the communication with a Host computer. The Host computer may communicate through a serial or parallel I/O. Because the control system has an expert system with built-in mathematical models and intelligence for the system with luminent devices, once the software enabled control system has been configured and given set points for desired target performance, it will regulate performance of the system

with a luminent device in a manner that does not require intervention of the Host computer. The configuration database is generally not available to the user to ensure the system containing a luminent device is not accidentally changed. For some applications, the Host computer may be allowed access to portions of the Configuration database in order to modify the operation of the system. The system contains performance optimization monitors based on predetermined criteria. The results of the monitors are available to the user or a Host computer through one of the available I/Os.

An advantage of the present invention is that it allows flexibility to address various luminent devices using the same software architecture and similar algorithms. Thus, maximum leverage of code can be achieved.

Another advantage of the invention is that the control system can be configured to address a specific luminent device allowing for compensation of manufacturing.

Another advantage of the invention is that it is hardware agnostic. The control system can be configured to reside in a mixed signal microcontroller an ASIC or any other type of computer.

Yet another advantage of the software-enabled control is that models can be dynamically changed in light of changing environmental conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a System Configuration Method for a software enabled control system for luminent devices.

Figure 2 illustrates a Software Enabled Control System for luminent devices.

Figure 3 is a Servo Control for a Luminent Device, and

Figure 4 shows an embodiment of the Configuration Database.

DETAILED DESCRIPTION OF AN EMBODIMENT

There are four elements, which are part the Software Enabled Control for Systems with Luminent Devices. These elements are:

1. System configuration method;
2. Software Enabled Control System is a system that is reconfigurable and uses embedded intelligence and decision-making to control hardware or mathematical objects used in a luminent system;
3. A configuration database; and
4. Dynamic performance optimization.

System Configuration Method

Figure 1 illustrates a system configuration method 100 for a Software Enabled Control System 106. The method 100 consists of a Host computer 101 used for configuration of the Control System 106. The Host computer can also be part of a larger system. Some examples of larger systems are a network, a liquid crystal display unit, or system containing one or more lasers. The Host computer 101 contains a Configuration

Database 102. The Configuration Database 102 contains information necessary to configure the control system 106. Some examples of the type of information in the Configuration Database 102 are: Parameters used in a servo loop control algorithm, gain and offset scaling, and calibration factors for sensors used in the luminent device system, dynamic adjustments of wavelength for a laser, or selection of a control or calibration equation product. The Configuration Database 102 information is sent to the control system by means of a Host computer I/O 103, which can be serial or parallel. Data is sent to a Controller 104. The Controller is the hardware where the software enabled control system resides. The Controller 104 may contain processing functions, embedded programs, analog signal acquisition, and analog or digital I/Os. The database information 102 is placed in a Configuration Memory 105, which may be part of the Controller 104 but can also be an additional unit, such as a permanent storage unit consisting of optical or electrical storage technology. To create a new application, the Host Computer 101 retrieves configuration data from a database and places the appropriate information into the Configuration Memory 105, which is part of the Software Enabled Control System 106. By changing the information in the Configuration Database 102, the control system 106 then is able to apply control in the most optimal manner to the luminent system under control. Examples of data in the Configuration Database 102 are parameters for embedded equations, firing voltage for a fluorescent lamp, and information regarding electronic circuit connections.

Once the configuration is complete, the Software Enabled Control System 106 is able to

operate on its own without any assistance from the Host Computer 101 in the most optimal manner.

The Controller 104 is connected to the Luminent Device System 107 by means of General Purpose I/Os 108. These I/Os consist of digital input and output signals and analog inputs. The General Purpose I/Os 108 are used to obtain feedback information, and to issue control directions. The Luminent Device System 107 contains luminent devices and a variety of hardware used to produce light of various types. Examples of luminent devices are laser diodes, gas lasers, LEDs, and Cold Cathode Fluorescent Lights (CCFLs).

The Luminent Device System 107 may also consist of sensors, electronic drivers, electro-optical devices, and special purpose integrated circuits. The reader will appreciate that the Luminent Device System 107 can be any device or system circuit that has the objective of generating light of any form.

Software Enabled Control System

The Software Enabled Control System 106 is a software or firmware engine with embedded processes, algorithms, and special agents with an expert system. The engine is provided with specific details regarding the System 106 with Luminent Devices 107 by the data in the Configuration Memory 105. Once the Software Enabled Control System 106 is given the specific configuration information, it will operate independently to effectively

control any luminent device.

Figure 2 illustrates one of the numerous possible architectures for the Software Enabled Control System 106. The Software Enabled Control System 106 consists of an Operating System 201, which directs the operation of the various programs and the assignment of system resources. The Operating System 201 provides the flexibility to connect a variety of programs to be used by the control system in a modular fashion. A System Configuration 202 is a database, which contains the information necessary to set the specific modes of operation of the Control System 106 and also contains multiple mathematical models for the Luminent Device System 107. The Luminent System Controls 203 consist of a set of programs used to carry out controls of specific devices within the Luminent Device System 107. Examples of these type of programs are laser driver controls, pulse width modulators used to control cold cathode fluorescent lamps, laser wavelength tuner controls, and thermoelectric cooler controls. The Luminent System Controls 203 contain mathematical models and rules which are modified depending on the information set in the system configuration. The Host Communication Interface 204 is a program used to communicate with a Host Computer. Communication may be done through a serial I/O or a parallel I/O using a specific Serial I/O Driver 205 or Parallel I/O driver 206 respectively. Numerous protocols can be utilized. Examples of these protocols are I2C and RS232. The choice of the protocol for communication with the Host Computer is made by a selection in the system configuration.

The Analog I/O Drivers 207 are a set of programs that determine how the Control System 106 interacts with analog devices used in the Luminent Device System 107. In a specific

embodiment of a hardware implementation, the Analog I/O Drivers 207 may control analog to digital converters, or digital to analog converters. An Analog Signal Calibrator 208 is a software module used to process the input or output signal from the analog interfaces to the hardware in order to obtain precision data. For example, regarding analog inputs, the Analog Signal Calibrator 208 will contain an equation for each of the inputs. The equations may be linear or nonlinear and allow the program to apply corrections to the incoming analog data in order to obtain a high level of precision in the measurement. If a specific analog input behaves in a linear manner, the correction equations will be an equation of the form $y=mx+b$. The parameters m and b specific for the sensor will reside in the System Configuration 202 and will be loaded by the Host Computer 101 either at the factory or in the field where the Host 101 is part of a larger system.

The Expert System for Luminent Device Automatic Characterization 209 is a program, which characterizes the specific luminent device in a system. Due to manufacturing variations, a luminent device will exhibit variations in performance as determined by the specification parameters. An example of luminent device parameter variation is found in a control system for the Cold Cathode Fluorescent Lights. Each lamp will generally have a different strike voltage (voltage needed to first turn on a fluorescent lamp). In the case of a laser control system, each laser will have a different threshold and slope efficiency. The Expert System for Luminent Device Automatic Characterization 209 will utilize the analog inputs and outputs to collect data when the system is powered up. The data

collected is analyzed with mathematical and statistical tools to obtain a performance profile for the specific part. The performance profile is used to update model equations which in turn are used in conjunction with Luminent Device Controls 203 to drive the luminent device in the correct manner to obtain acceptable performance. The Expert System for Luminent Device Automatic Characterization 209 is initialized with the selection of an algorithm used to obtain the characteristic profile. Selection is carried out through a flag that is set in the System Configuration 202.

Luminent Device Controls 203 consist of a set of algorithms used to drive a luminent device. The control algorithms may be servo controls, or other type of controls. The Luminent Device Controls 203 are initialized for the specific luminent device with parameters in the System Configuration 202. For example, in the case of a servo type of control, the System Configuration 202 will store the damping coefficient and the servo gains used for the servo control of the luminent device.

Figure 3 illustrates a model for servo control of the lamp output. Luminent Device Controls 210 are a set of programs used to control the operation of the luminent device. These programs may consist of servo controllers or another type of control programs. Some other programs in the Luminent Device Controls 210 are the result of a characterization of the luminent device. The characterization is then rendered to a model, which resides in the Luminent Device Controls 210. The System Configuration 202 then determines how the model is applied. As an example, consider the performance of a laser diode over temperature. The slope efficiency (output power per current into the laser), threshold current, and wavelength vary in accordance to generally nonlinear relationships

versus temperature. These relationships can be rendered into a formula with parameters. The parameters are initialized in accordance with data in the System Configuration 202, thereby allowing the customization of the control for a specific unit. The objective of the Luminent Device Controls 203 is to obtain a set point for any performance parameter of a luminent device.

An embodiment of the Luminent Device Controls 210 is a servo control system. Servo systems have traditionally been used in motion control applications. This invention uses servos to solve problems with for luminent devices.

Figure 3 illustrates a Servo Control for a Luminent Device 300. Starting with a set point 301, the System 106 will continuously operate in a manner that will automatically adjust an Output 307 to the value of the set point 301. The Output 307 is any controlled variable of a luminent device 306. Examples of controlled variables are luminance of a Cold Cathode Fluorescent Lamp or, the wavelength, power, or current of a laser. An error 303 corresponds to the difference between the set point and the measured value of the Output 307 as given by a Feedback 302. A Servo Controller 304 is a control process that determines the best way to drive the luminent device 306 in order to maximize the speed at which the Set Point of the control variable is achieved in a smooth and stable manner. The Servo Control for a Luminent Device 300 also consists of one or more Sensors 308 that measure the Output 307. Once the Output 307 is measured, the signal is digitized with an A/D converter 309 and may be processed with a Signal Processor 310 to maximize signal to noise ratio.

Servo controls offer numerous advantages. Since there is a continuous monitoring and adjustment of the Output 307, the result is very precise. The various elements of the block diagram can be calibrated to a high degree of precision with appropriate parameters in the System Configuration 202. In addition, the various blocks of the servo can be configured to address the control of any controlled variable.

Configuration Database

Figure 4 shows an embodiment of a Configuration Database 400 used for a laser control system. Column 401 displays examples of the diversity of parameters that the database contains. Parameters such as Laser Servo Gain, Servo Damping Coefficient, Measured Feedback, and Set Point for Extinction Ratio modify the performance of a feedback control system. The Overload detector and Eye Safety Shutdown settings modify operation of built-in programs. Threshold Detector Result and Temperature are results from measurements, which continually change while the Software Enabled Control System 106 is running and will generally be assigned to RAM locations. Flag for Selection of Laser Control Program selects from various programs for laser control the best match to the application. Scaling Factors for Drivers, Analog input 1 sensor offset, and Analog input 1 sensor gain relate to calibration of a sensor input and allow the use a variety of hardware platforms. Temperature coefficient for slope efficiency and the Exponential for Threshold equation modify mathematical models for laser characteristics in order to customize the control to a specific device. More than one model of temperature

compensation can be made available depending on the specific laser. The specific compensation is chosen with the Flag to select the type of temperature compensation. The TEC set point and Wavelength set point are used to set the target values for servos used in wavelength tuning applications. The System resolution entry in the Configuration database 400 allows the use of A/D and D/A converters with 16, 12, 10, 8 or less bits of resolution. The Receiver gain setting is used to control the gain of an amplifier used in an optical receiver. Column 402 is the symbol for the parameter in the database. The Value 403 of the parameter in the Configuration Database 400 is loaded through a data path 404, which uses a serial or parallel I/O. The data is provided by a Host computer 101 in the factory or in a field installation for a system or product.

Dynamic performance optimization

The software enabled control system contains built-in intelligence to regulate performance of the system with luminent devices. Once the system has been configured, it is independent of the Host computer 101. The Software Enabled Control System 106 is capable of generating its own diagnostics with built-in data monitors. One of these monitors is a Servo data log. The objective of the Servo data log function is to record the information of the critical parameters that determine servo performance. Whenever a servo loop is executed, the values of several servo variables are recorded in RAM. Examples of stored variables in the servo performance monitor are:

- PM. (Measured feedback),
- Err (loop error),

- PS (set point),
- PCONT (Servo control value), and
- Drive (Driver input to modify variable)

The System 106 has predetermined criteria in the Configuration database 400 used to check results of the servo operation. The criteria can be degree of stability of the controlled variable. All of the information obtained from the operation of the software enabled control system 106 is dynamically updated. This information includes performance measures, digital I/O port and analog I/O port status. The information can be made available to the Host computer 101 to inform the status of performance gages. Examples of gages are the percent of life remaining for the luminent device or any other failure mechanisms encountered that may warrant part replacement.